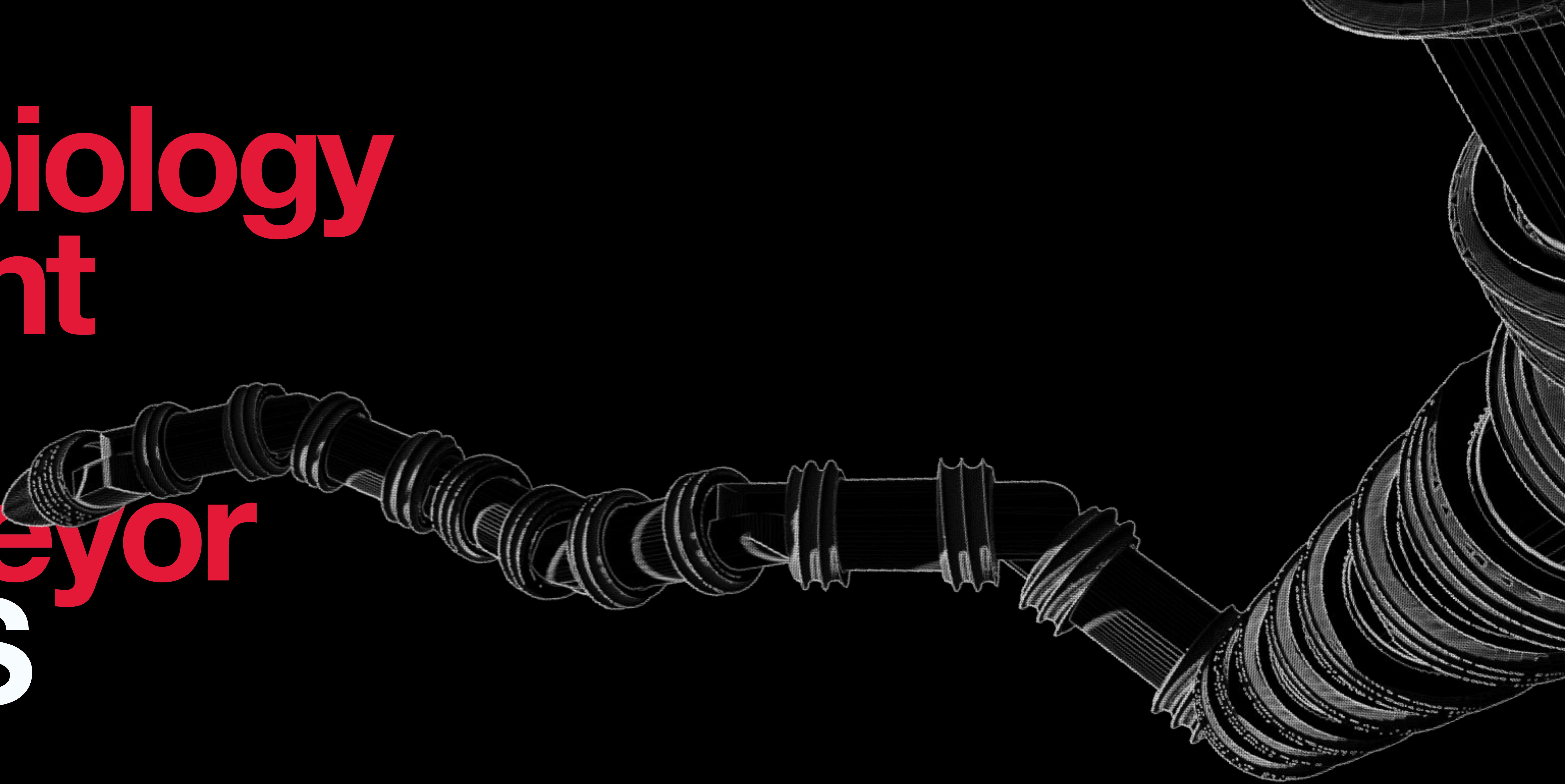
Exobiology Extant Life Surveyor

EELS



EELS Mission Concept Special Presentation

Jet Propulsion Laboratory
California Institute of Technology

Pre-Decisional Information – For Planning and Discussion Purposes Only.

Concept Why Enceladus?

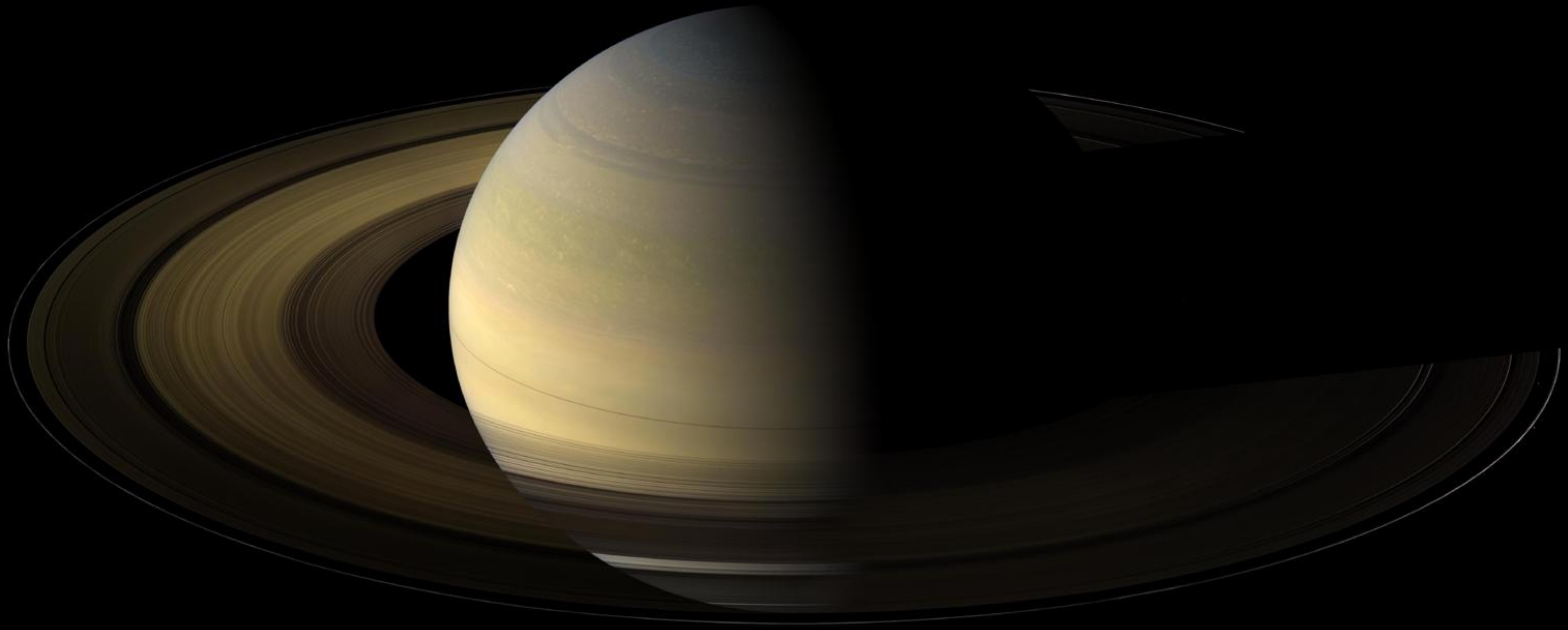


Image: NASA-JPL/SSI

Concept Why Enceladus?

Image: NASA-JPL/SSI

Concept Why Enceladus?

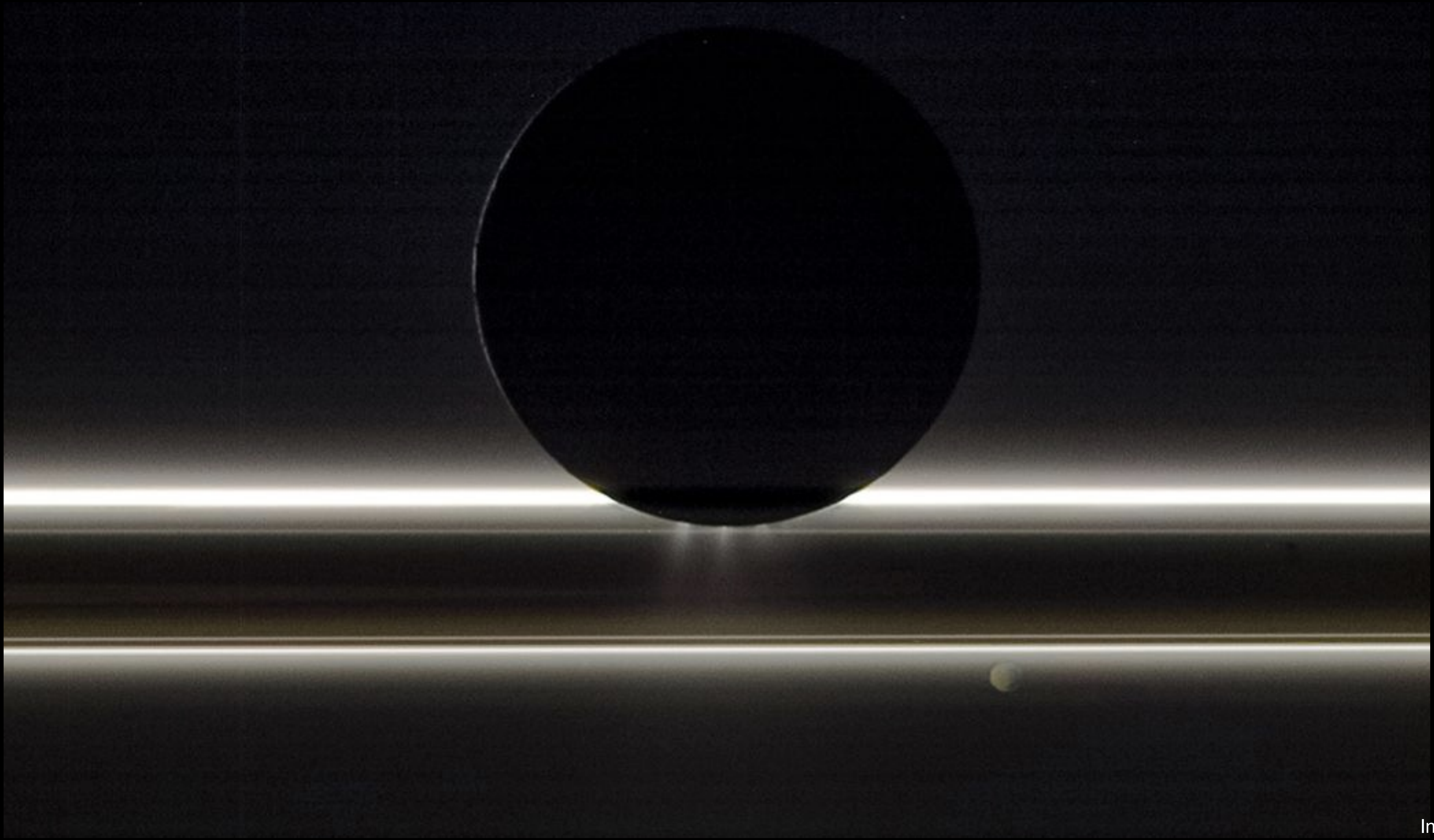


Image: NASA-JPL/SSI

Concept Why Enceladus?

Image: NASA-JPL/SSI

Concept Why Enceladus?

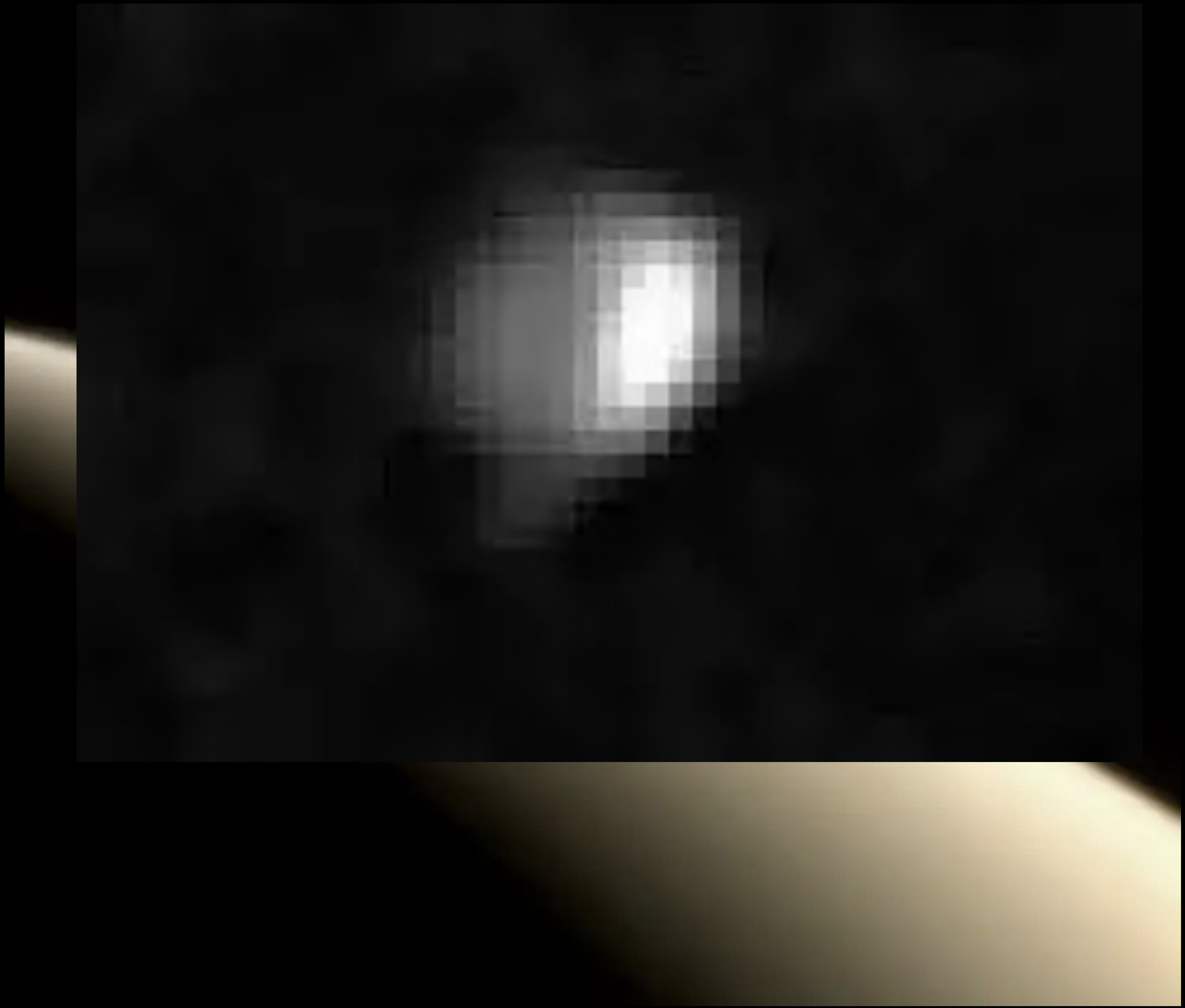


Image: NASA-JPL/Ted Stryk

Concept Why Enceladus?

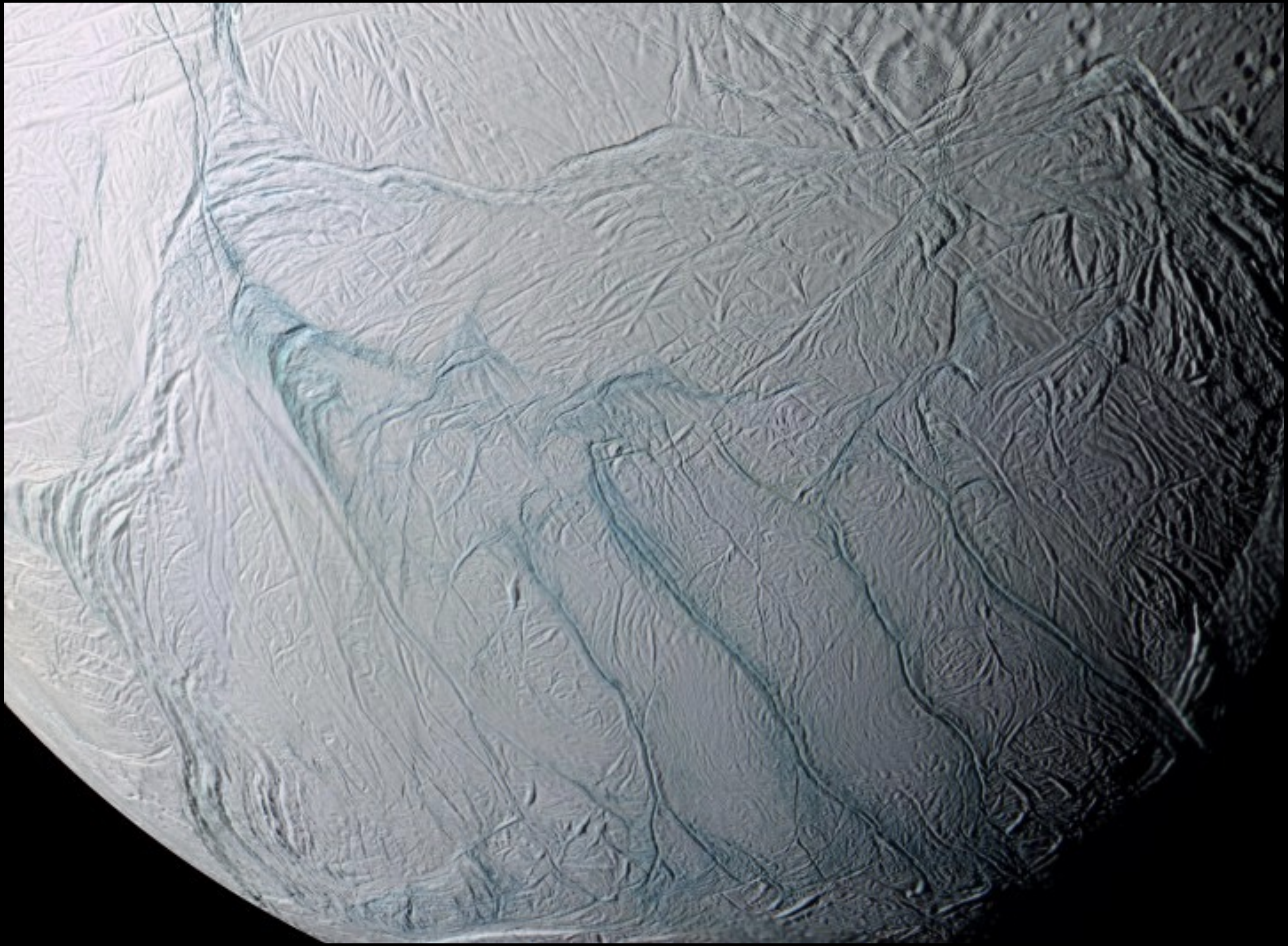


Image: NASA-JPL/SSI

Concept Why Enceladus?

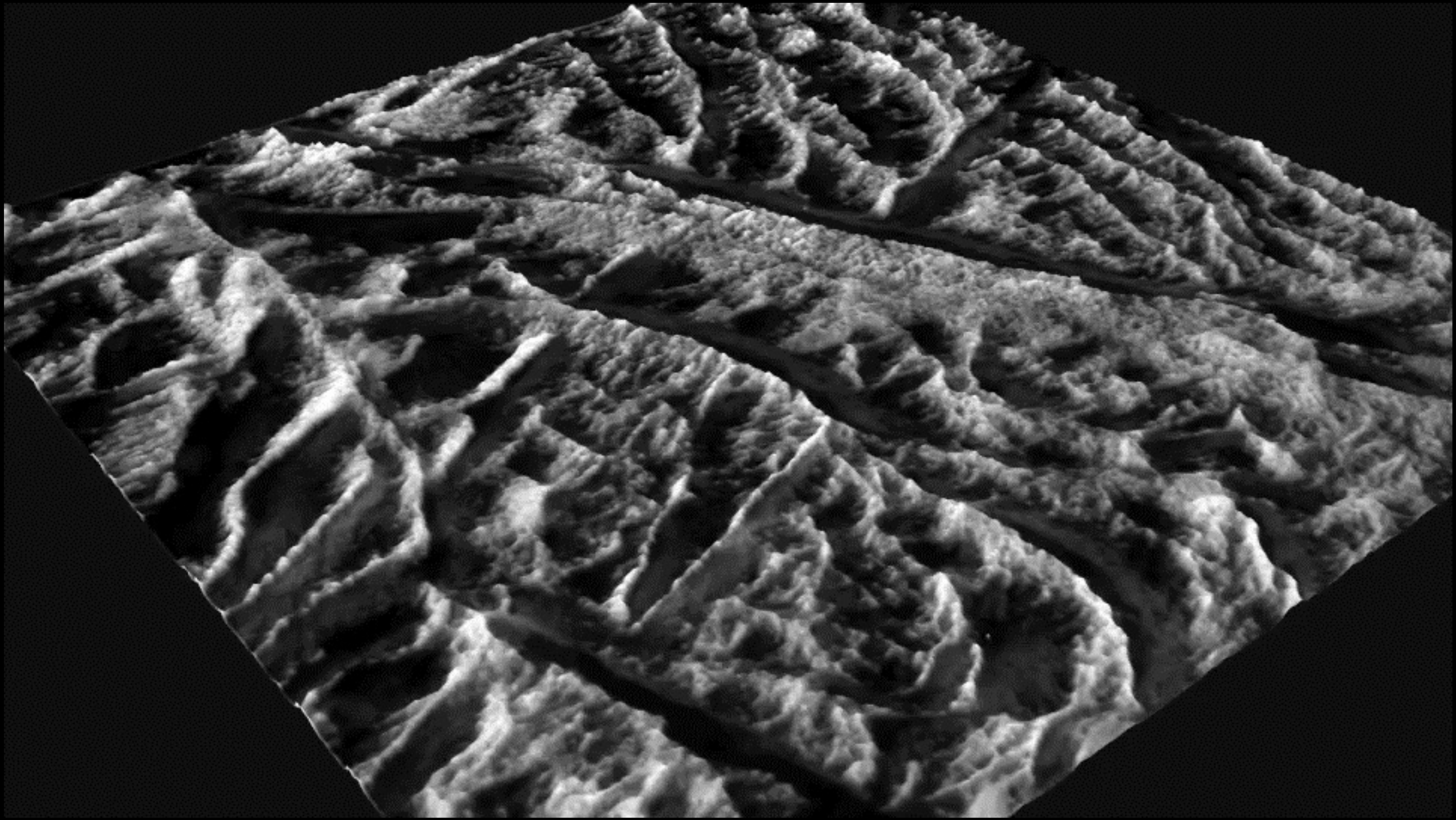


Image: NASA-JPL/SSI

Concept Why Enceladus?

Concept Why Enceladus?

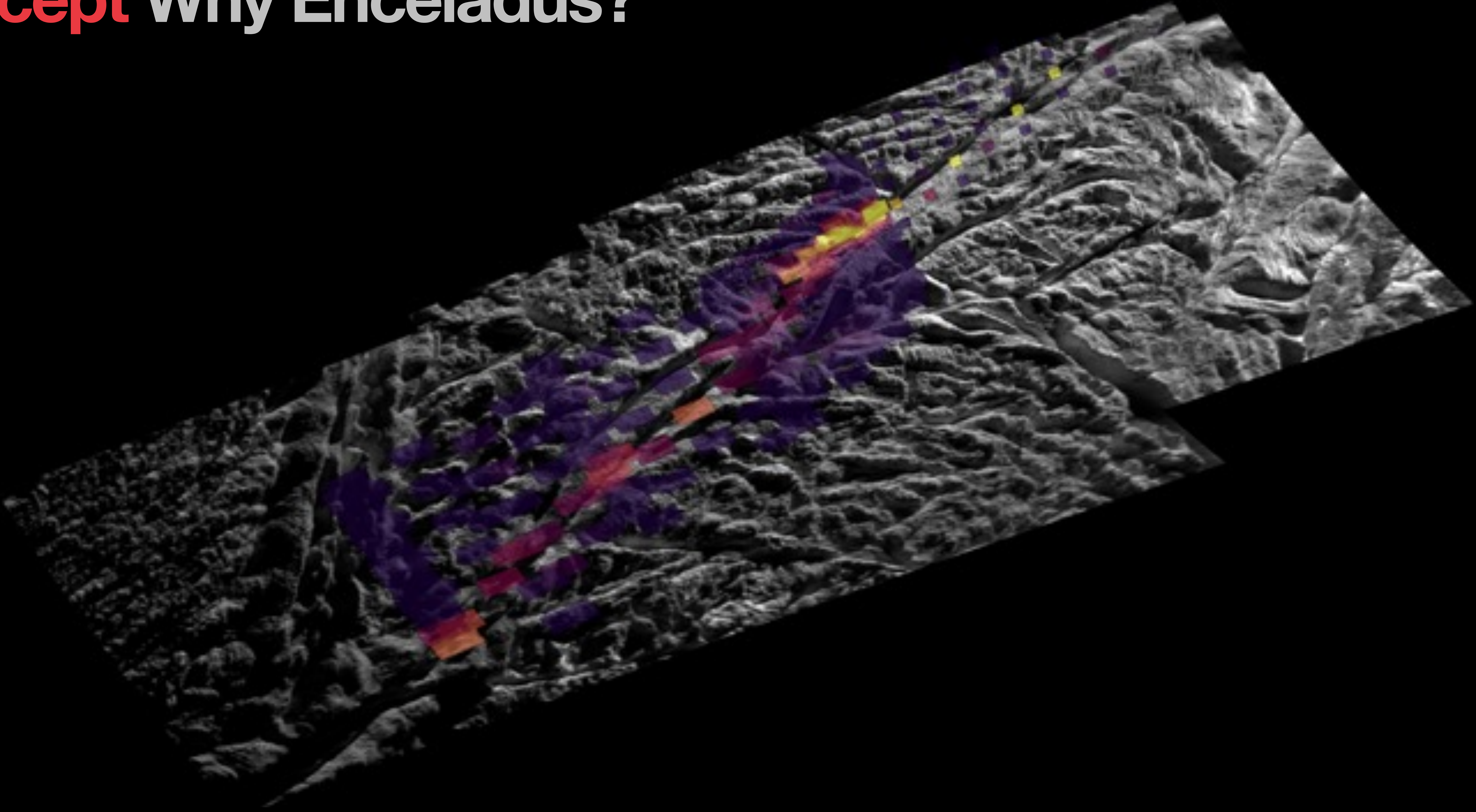
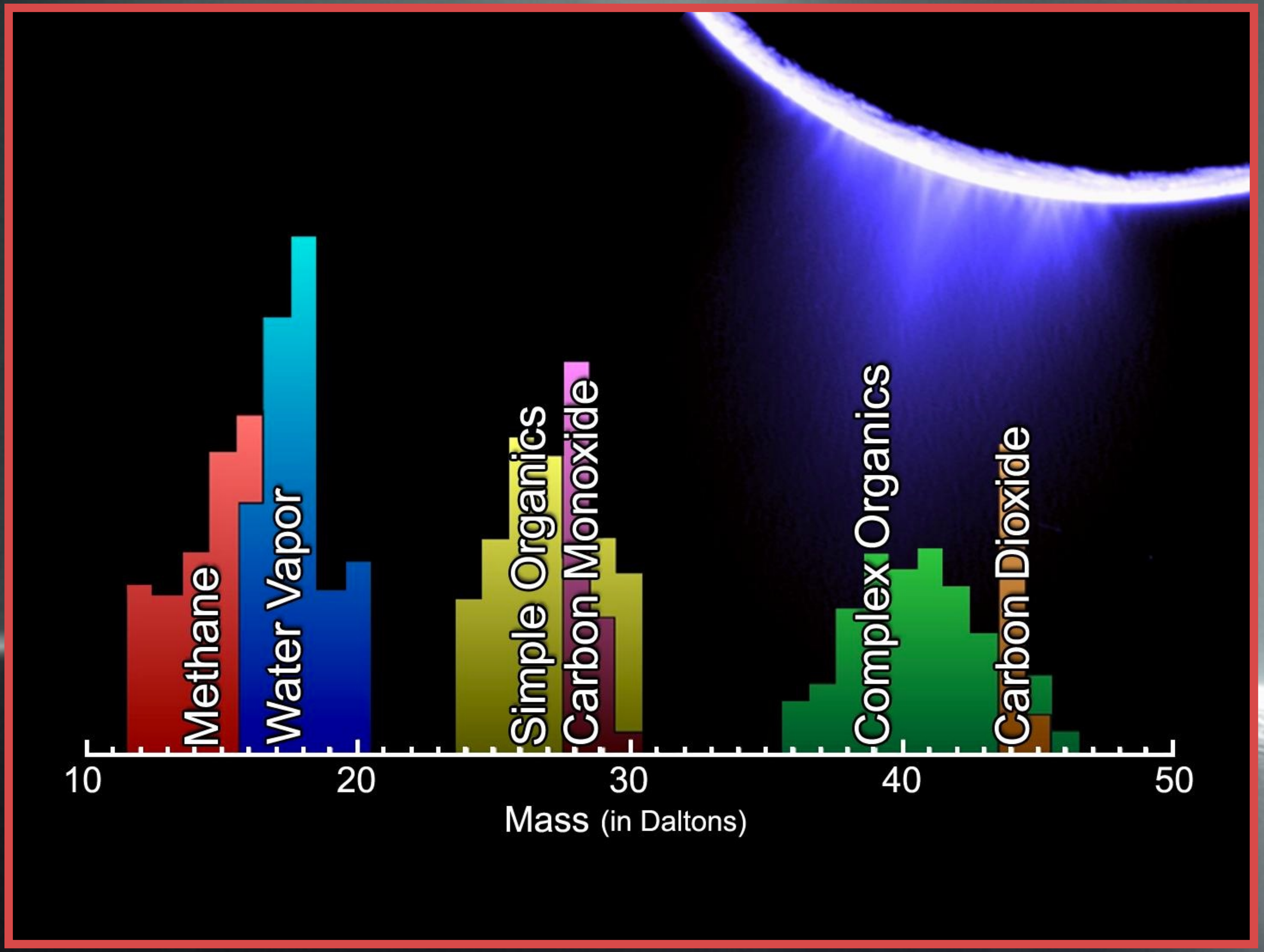
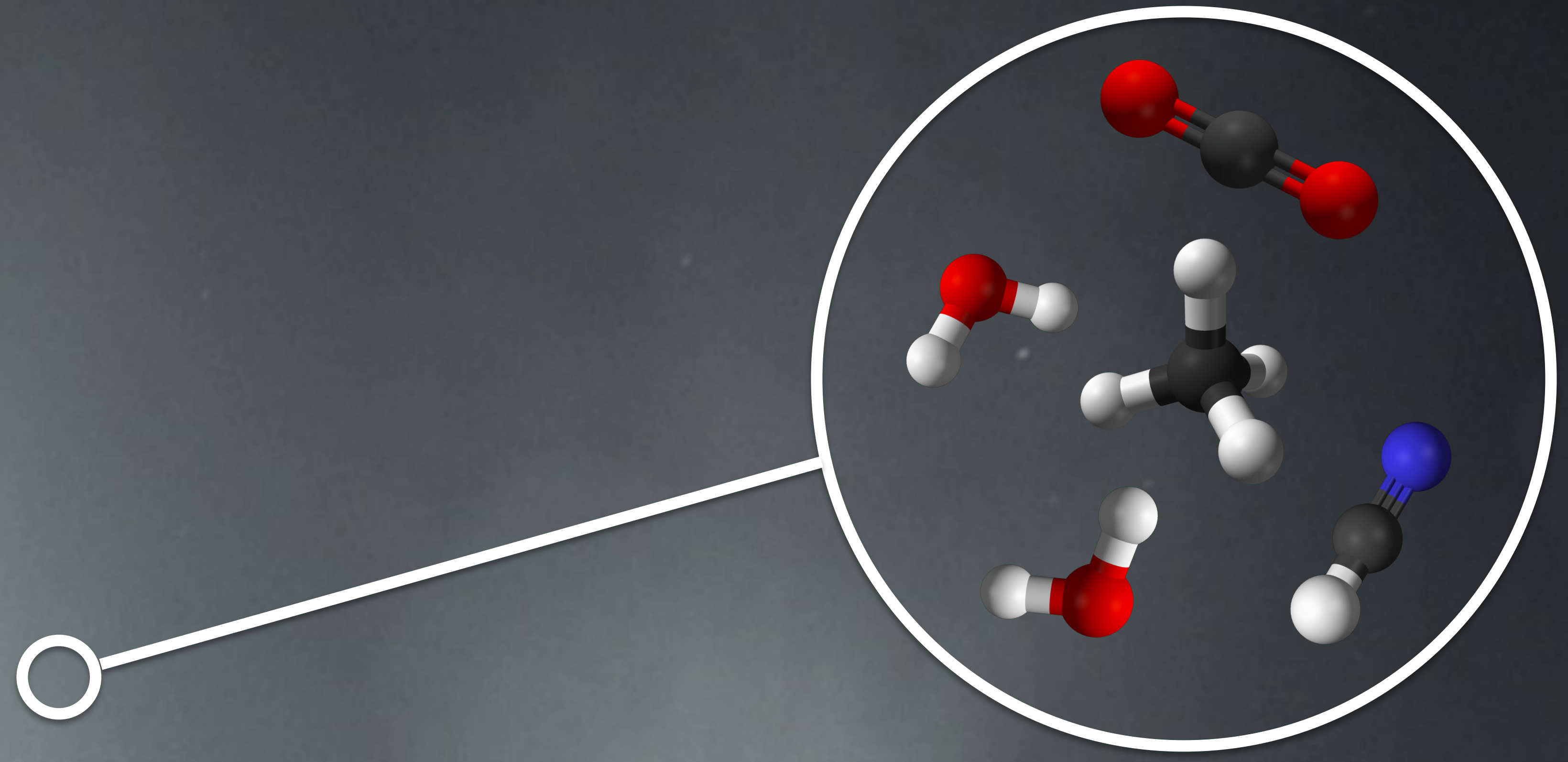


Image: NASA-JPL/SSI

Concept Why Enceladus?





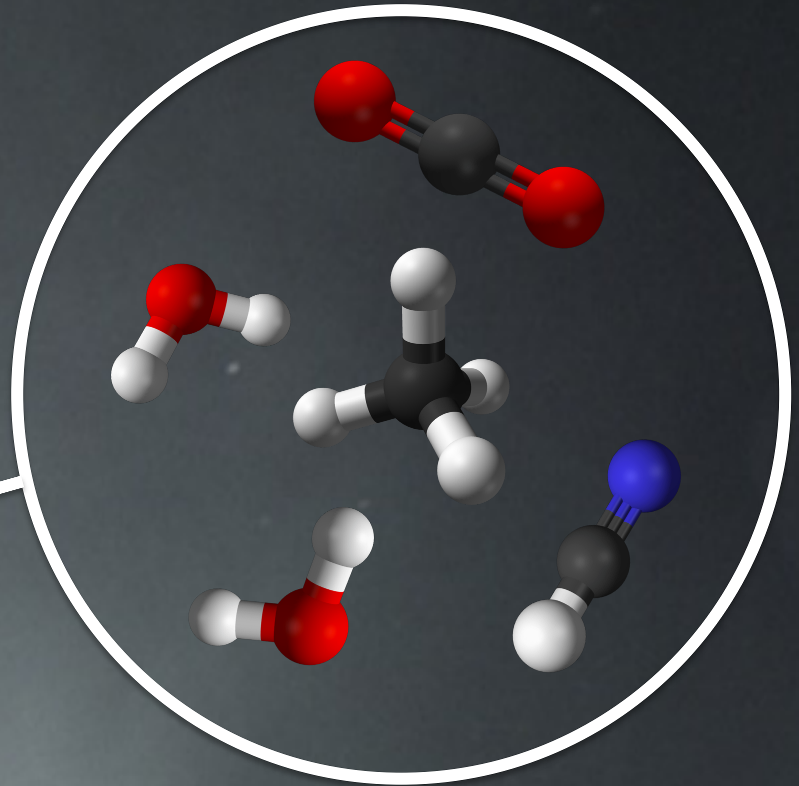
Plume gas

- Water, carbon dioxide, methane, ammonia, molecular hydrogen (H_2)
- Simple and complex organic molecules

Concept Why Enceladus?

Plume grains

- Water ice, sodium chloride (like our oceans)
- Large organic molecules



Plume gas

- Water, carbon dioxide, methane, ammonia, molecular hydrogen (H_2)
- Simple and complex organic molecules

Concept Why Enceladus?

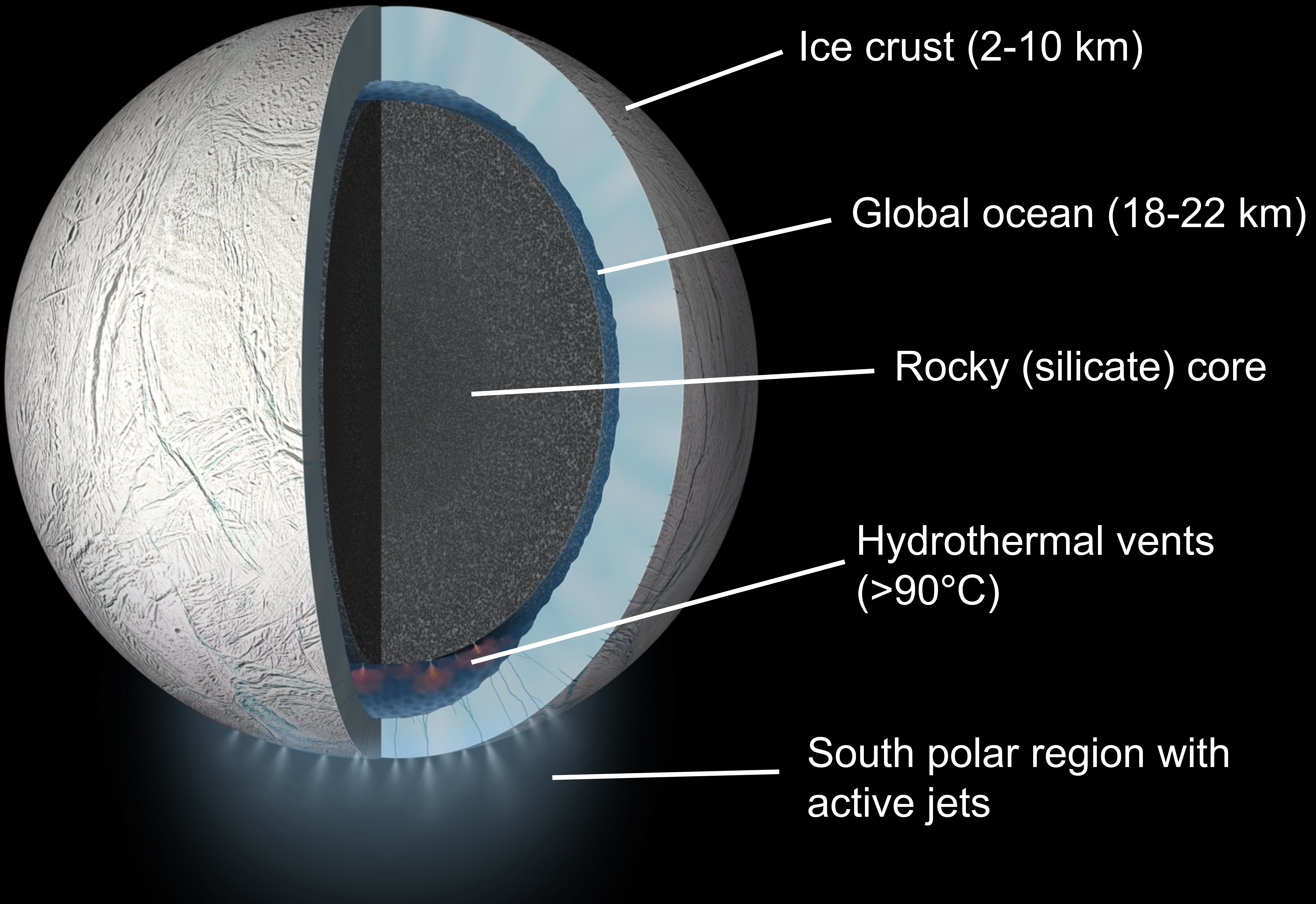
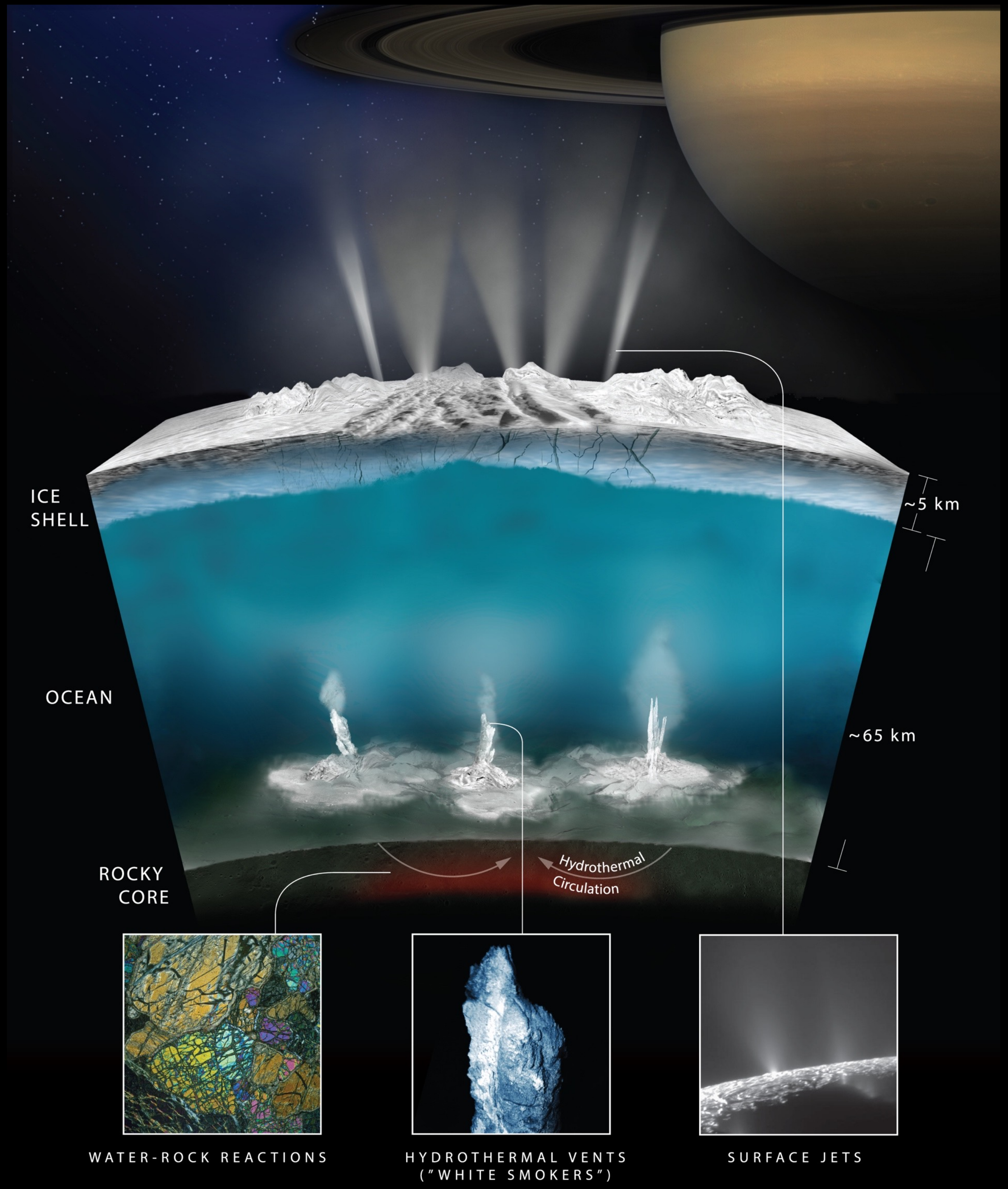


Image: NASA-JPL

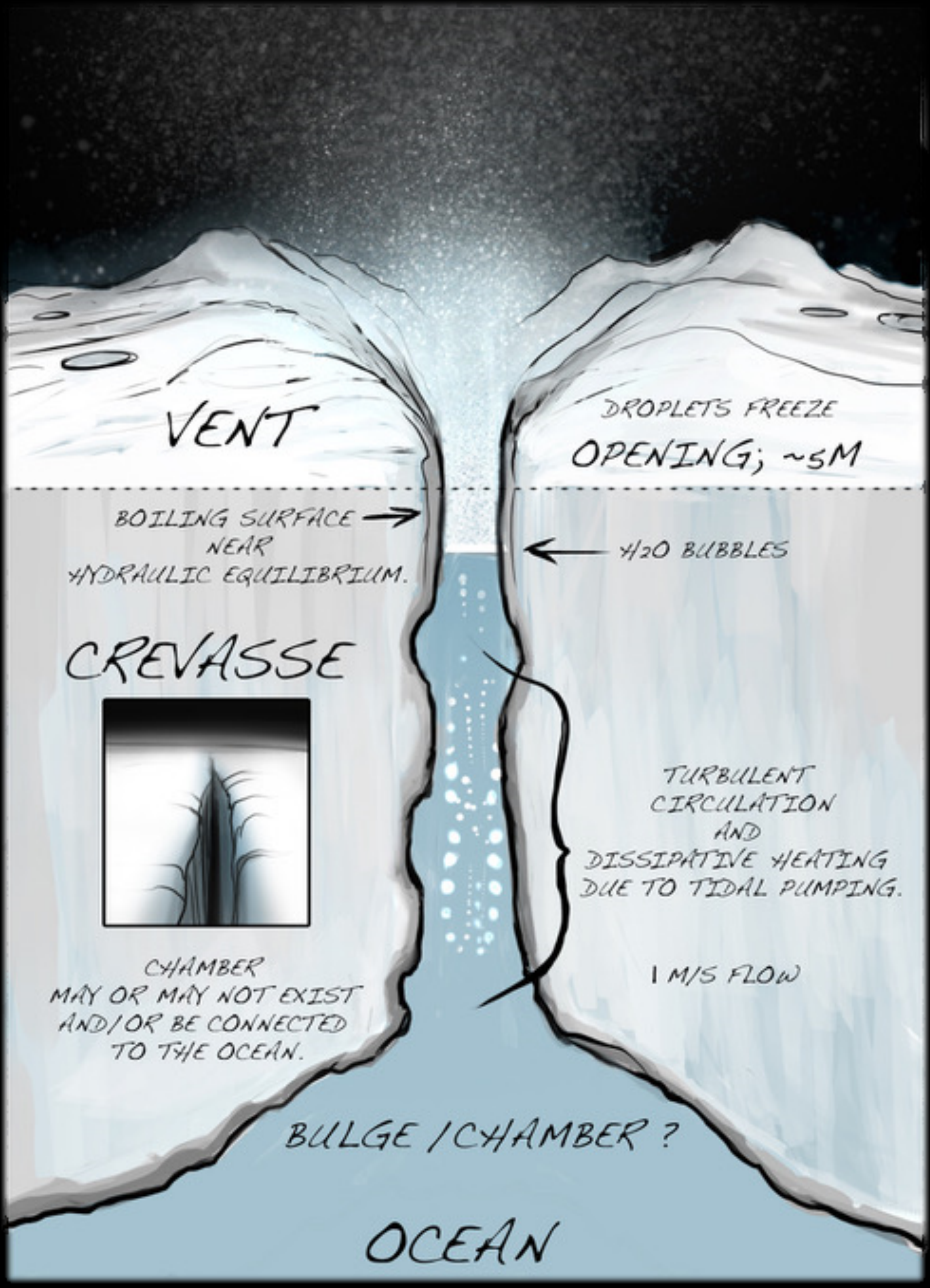
Concept Why Enceladus?

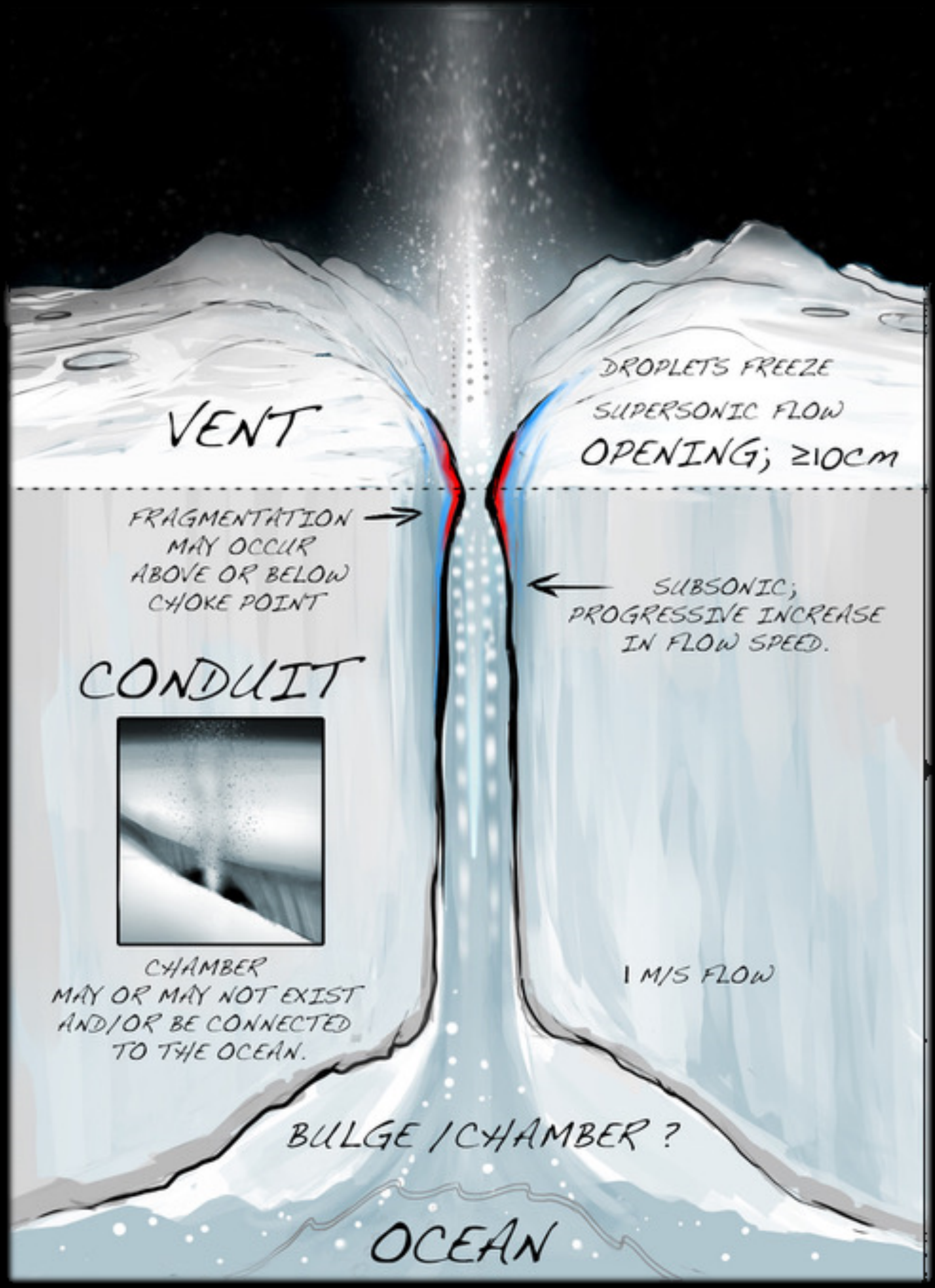


Concept Science Return

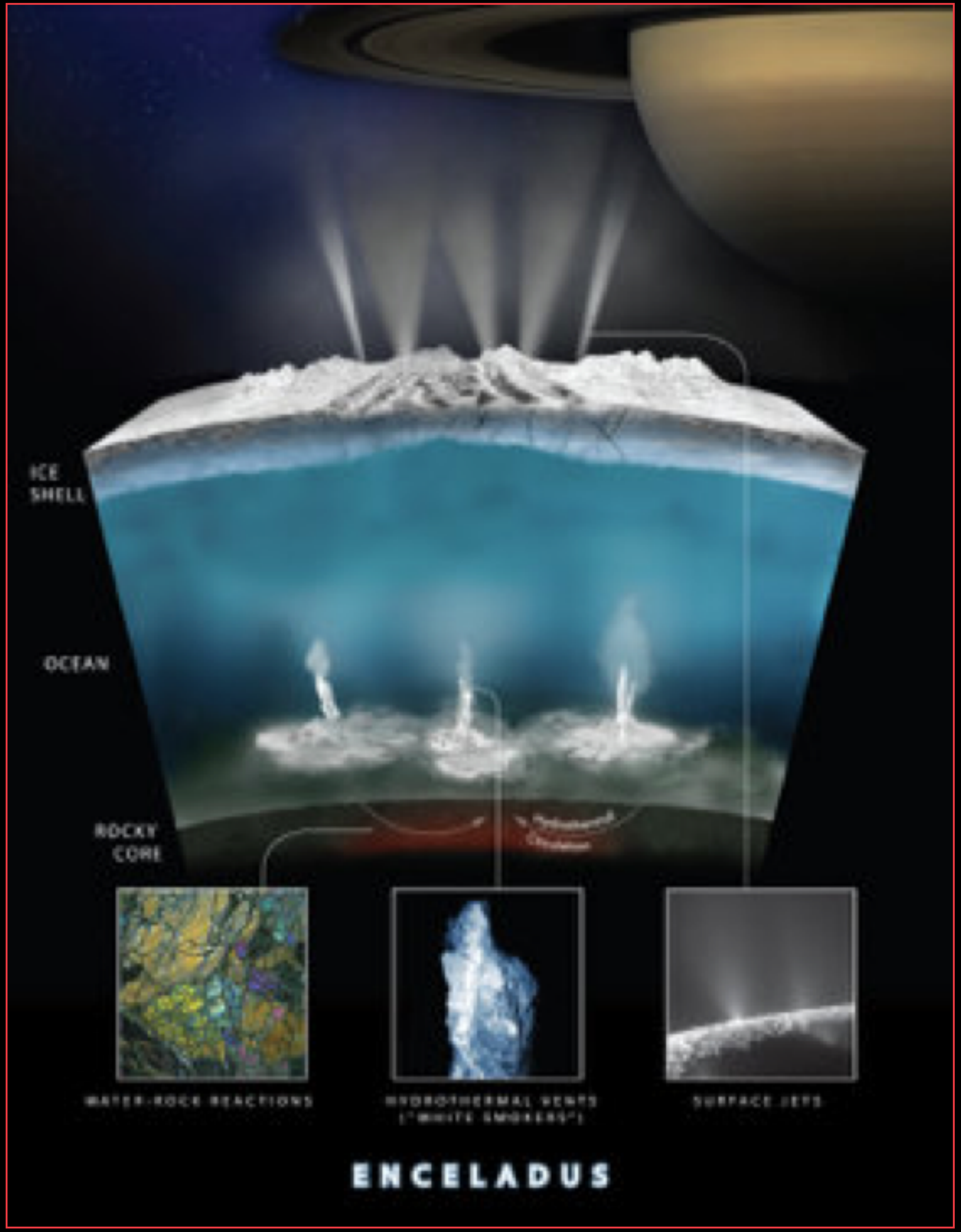
	Science Goal	Science Objective	Measurement Objective
Astrobiology	Search for evidence of life at Enceladus.	Detect and characterize organic indicators of extinct or extant life.	Quantify amino acids relative to glycine to establish biotic vs abiotic ratio, and determine their chirality.
			Quantify fatty acids relative to C12 (dodecanoic acid) to search for even/odd or other pattern different from Fischer-Tropsch synthesis.
			Determine $^{13}C/^{12}C$ and D/H ratios in various alkanes to search for evidence of biological synthesis.
			Quantify the amount of ATP present as an indicator of microbial activity.
		Detect any morphological indicators of life.	Identify any cells via imaging, composition and/or motility.
			Search for microbial mats, biofilms or biominerals.
Habitability	Assess the habitability of the Enceladus ocean.	Determine the physical characteristics of the Enceladus ocean.	Measure ocean temperature, specific conductivity, and turbidity.
		Determine the chemical characteristics of the Enceladus ocean.	Measure salts and volatiles to determine ocean pH and redox potential.
			Search for energy sources available for life (redox pairs for chemosynthesis, dissolved volatiles, etc.)
Geology	Characterize the internal structure of Enceladus.	Determine ice shell thickness and depth of ocean.	Measure acoustic signals of reflecting body waves using geophone or seismometer.
		Determine vent eruption mechanism.	Measure changes in vent opening and gas/particle flux with orbital period.

Concept Why Reach the Ocean?





Concept
Envelope of Critical Parameters



	Source	Envelope
Mass flux	Cassini	250 Kg/s (Tidal dependent)
Exit Velocity	Cassini	240-1000 m/s (Height independent of tides)
# of vents	Debated	>100
Dynamic pressure	Debated	~0 Pa
Ice Thickness	Cassini/ Debated	2-30 km
Shape	Debated	Fissure vs point sources
Plume throat	Debated	2 mm - 140 mm (Low end is likely implausible due to heat balance, >70 mm likely)
Particle size	Cassini	<100 micron
Vent static pressure	Debated	~0 kPa-9E^5 kPa

Instrument Technology Investments

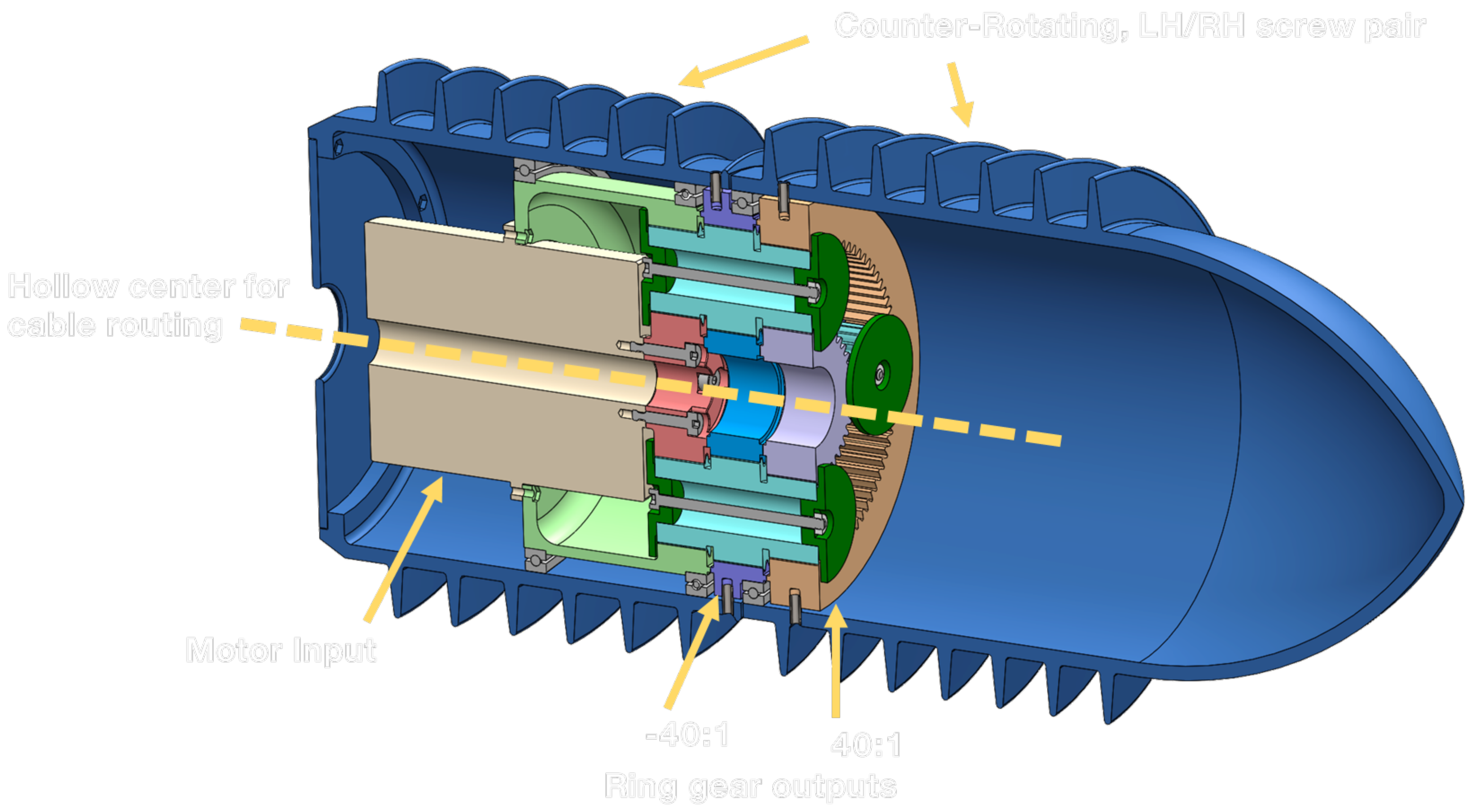
- Front end. We need access to ocean liquid and plume grains. Some kind of liquid ‘sipper’ is needed, in addition to a plume grain collector.
- Concentrator. Depending on biosignature targets, sample concentration may be needed to achieve required limits of detection for trace species.

Technical Goals Flow Sensing

Technical Goals Adaptive Force Control

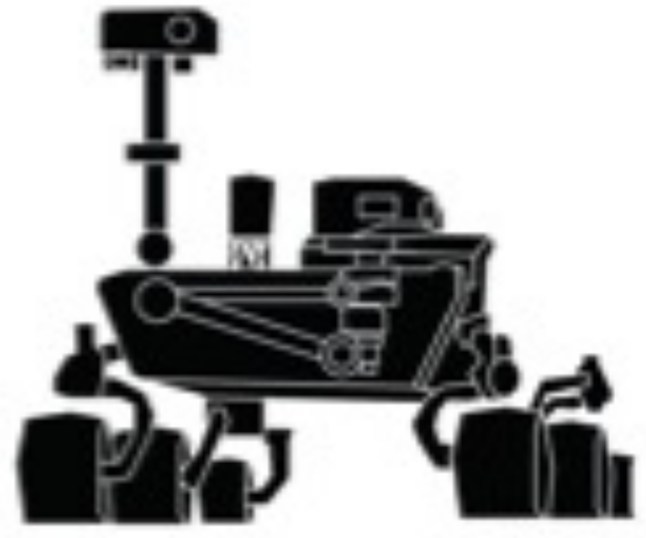
Technical Goals Actuators & Gears

EELS Actuator and Screw Mobility Prototype
Integrating Highly Compact, Torque-Dense Bearlingless Planetary Gearbox



Autonomy Challenge Rate of Traverse

M2020



MARS YEARS:

1.25

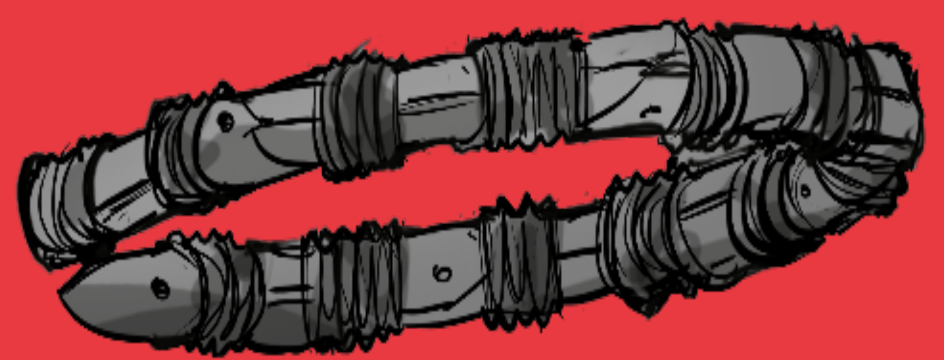
DISTANCE TO COVER:

15 km

SAMPLES TO COLLECT:

20 drilled samples

EELS



Earth hours

16

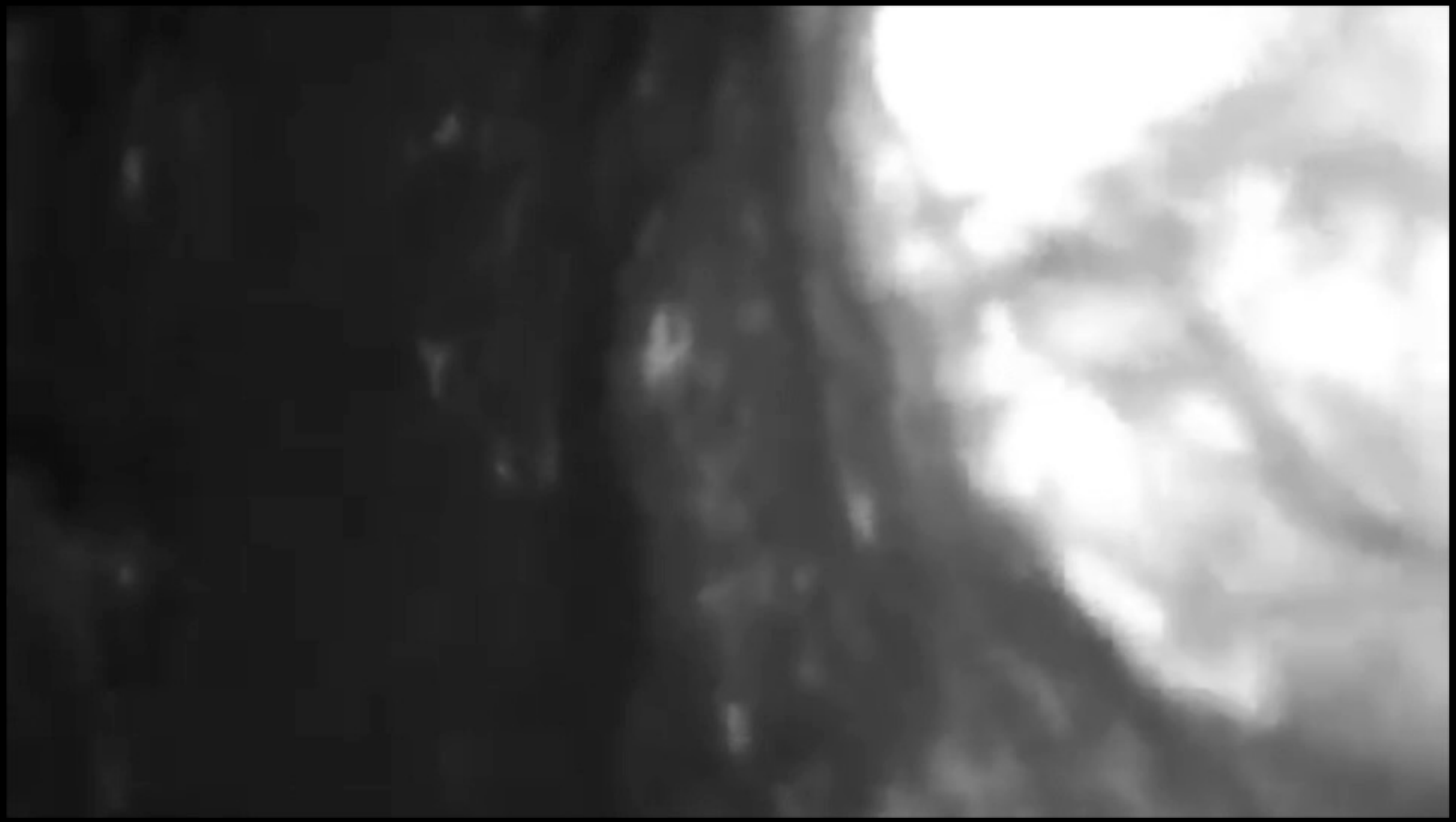
Distance to cover:

Up to

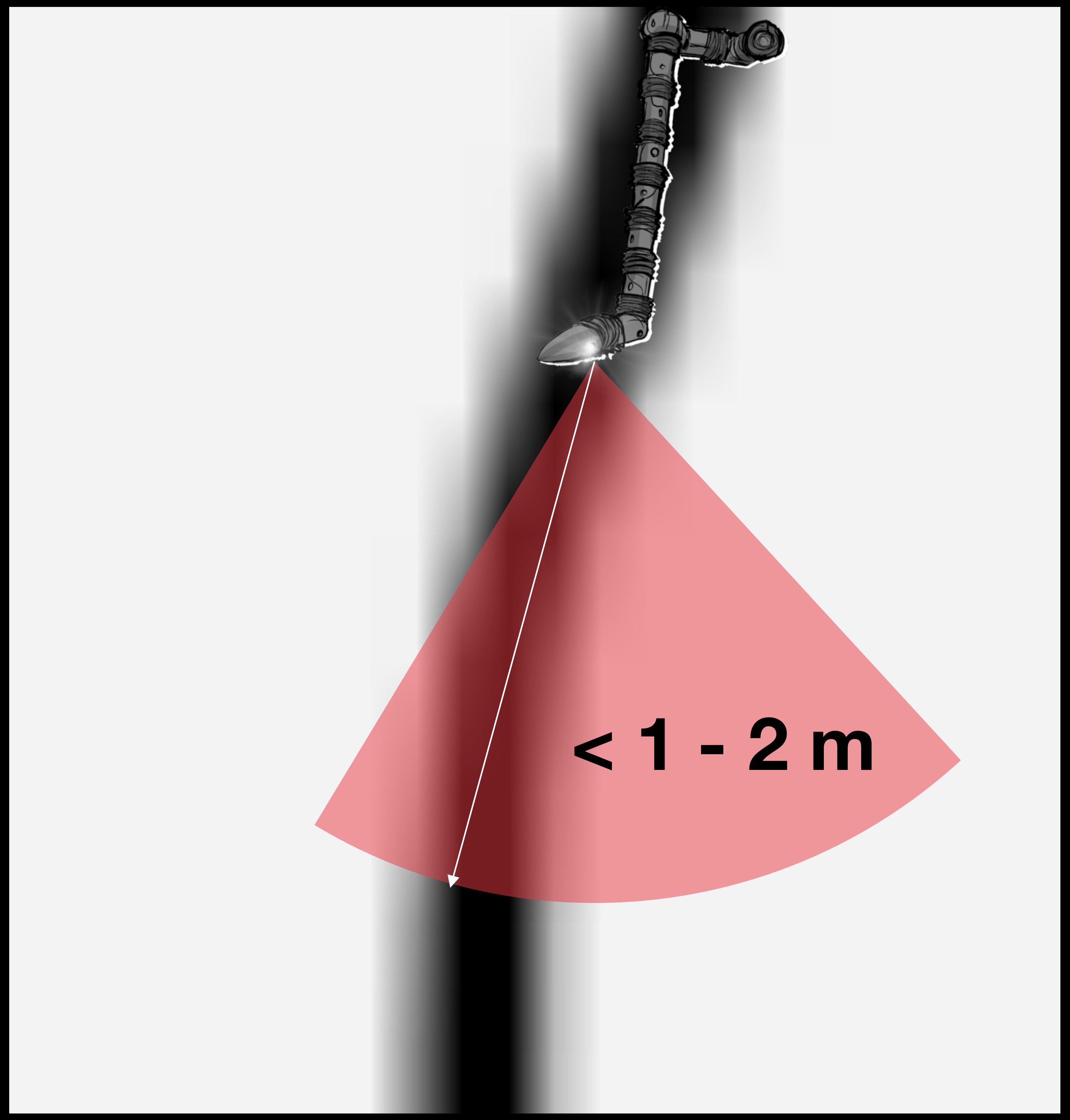
3 km

Vertically

Autonomy Challenge Visibility



Interior of Old Faithful
J. Westphal, S. Sieffer, R. Hutchinson (1993)



EELS Autonomy Principles

EELS

Conventional missions

Reactive

Select activities in response to events

Deliberative

Plan & schedule activities in advance

Adaptive

Change behaviors to accommodate *observed* situations

Robust

Preprogrammed behaviors that work for *any* imaginable situations

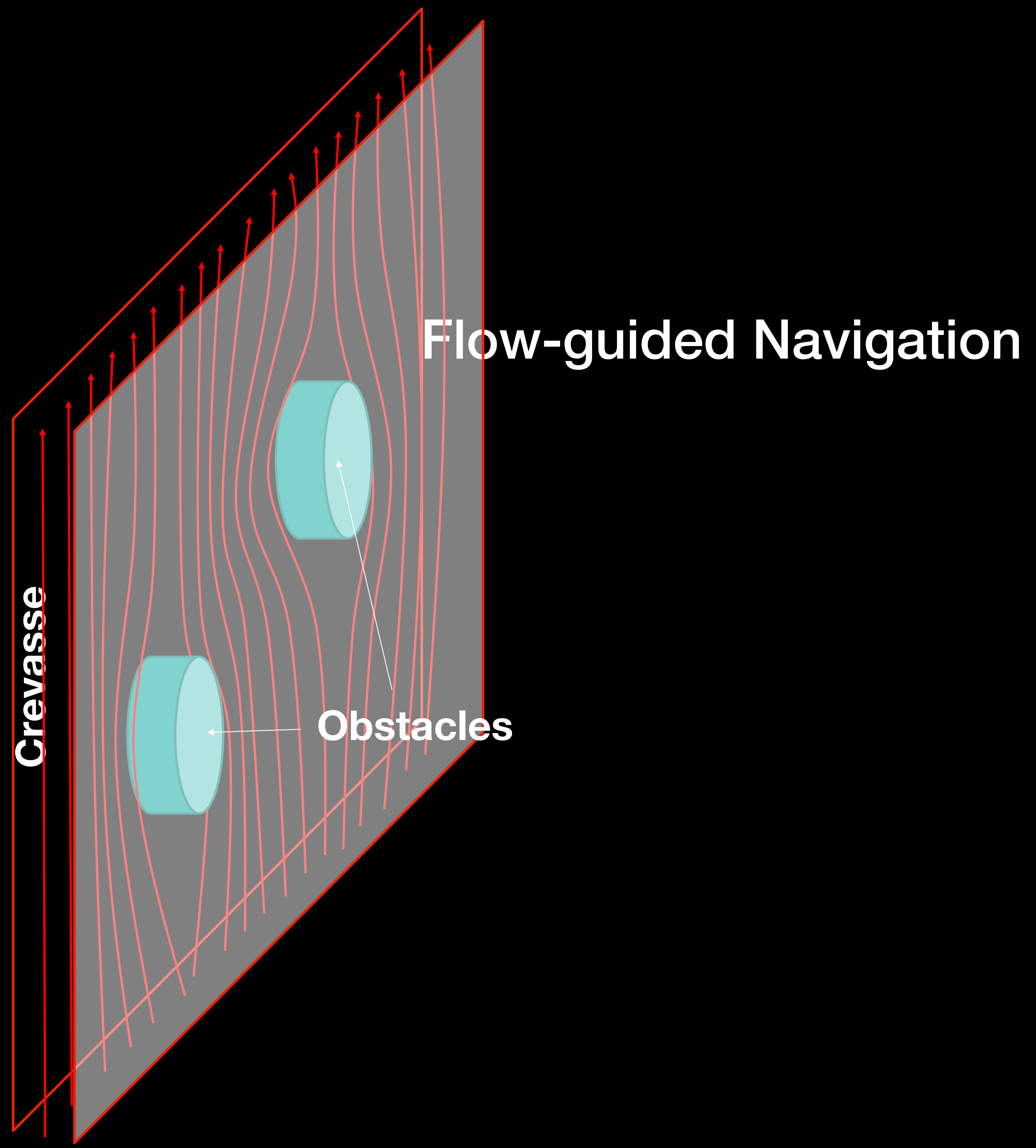
Resilient

Keep going with remaining capabilities

Protective

Stop activities, go into safe mode, and wait for the ground

Flow-guided Navigation

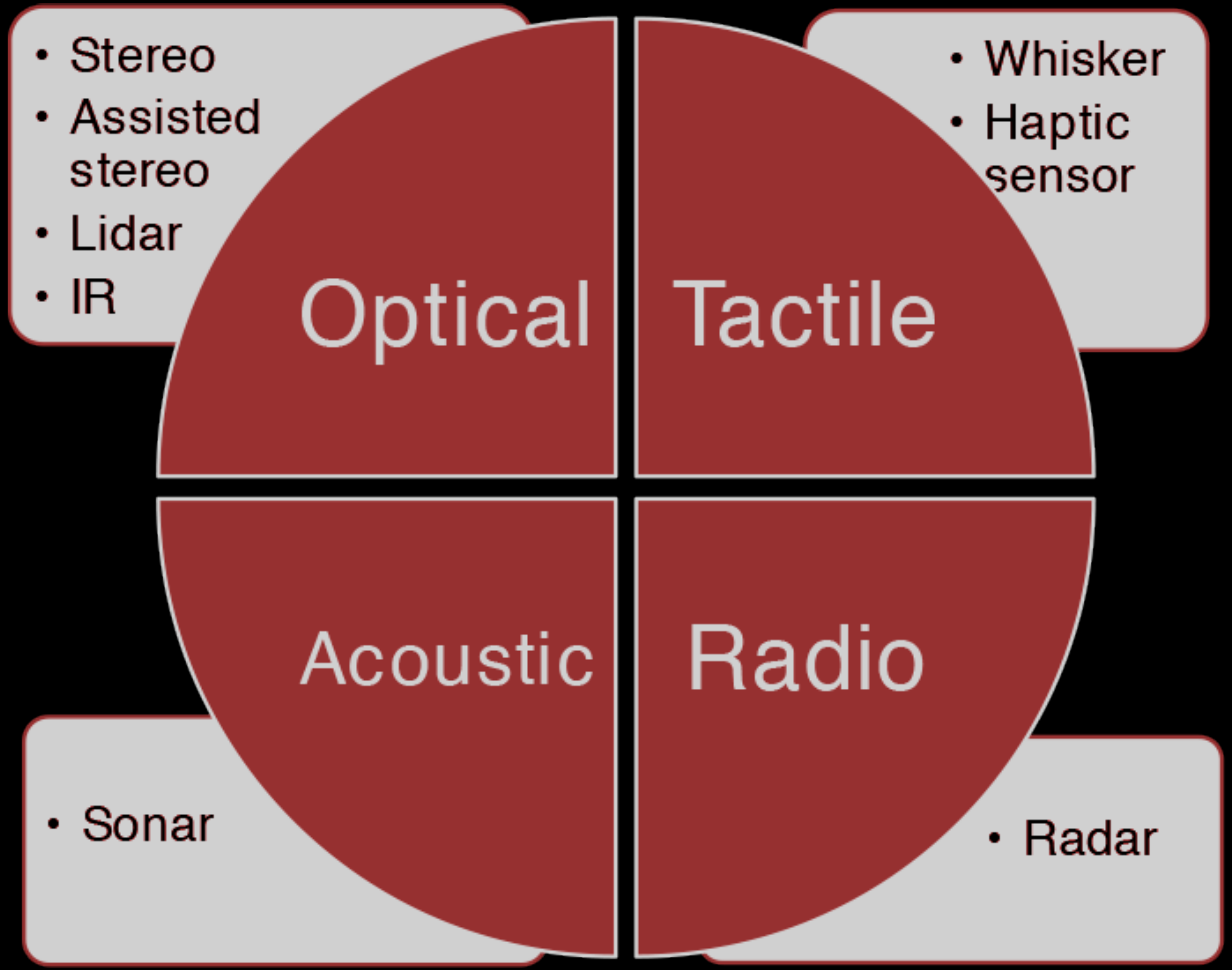


Adaptive gait control

Shape-based admittance control

Movies by Howie Choset, CMU

Resilient perception with sensor fusion

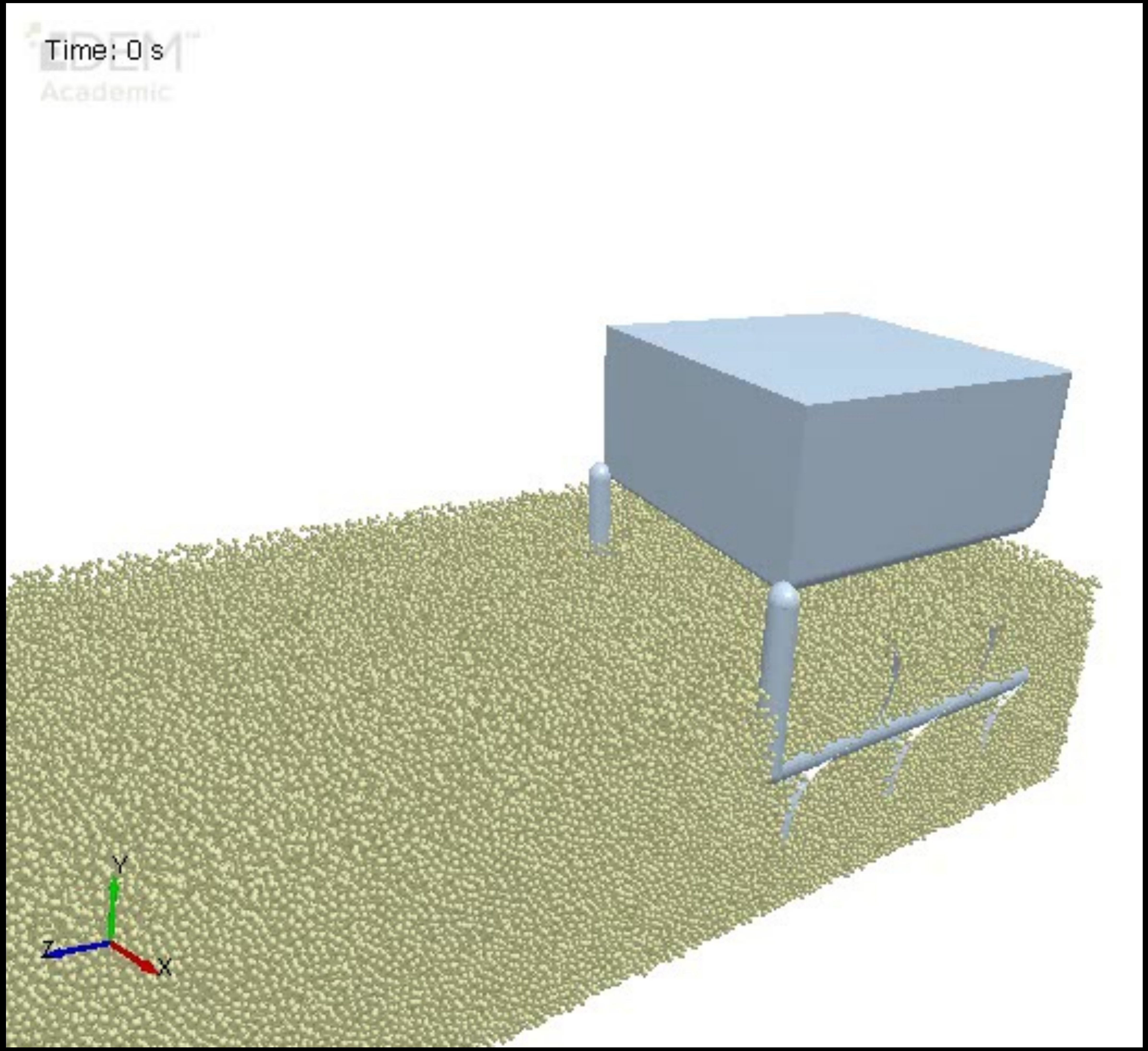


De-rain/de-haze
Movie by S. Narasimhan, CMU

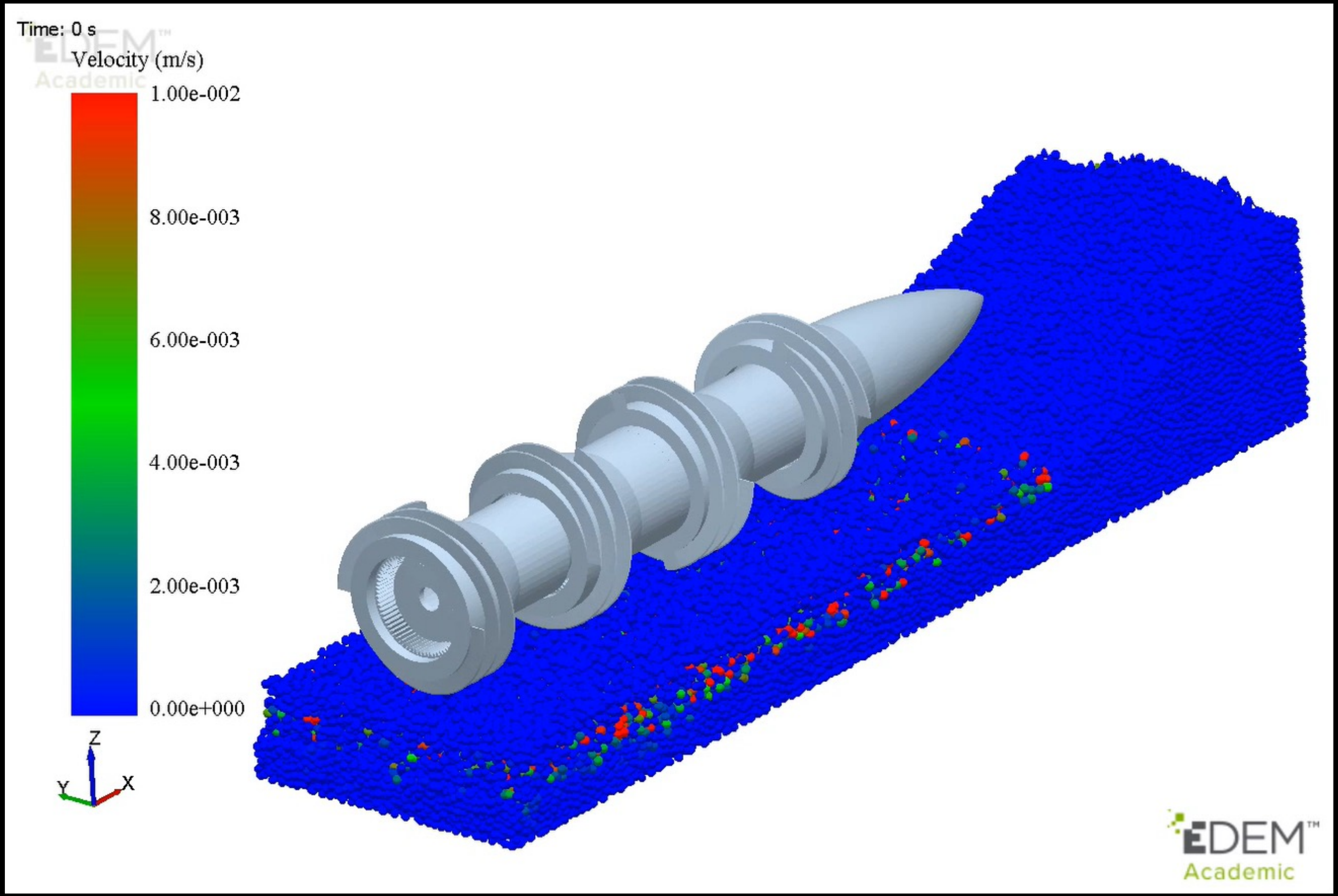

Rigid Pose
Nose Pitot Pressure
NoseCam
Pose
Science Instruments
00:05:00
EEL
Pose Change
NoseCam Capture
Pitot Flowspeed
Tether Tension
Temp °C
IMU

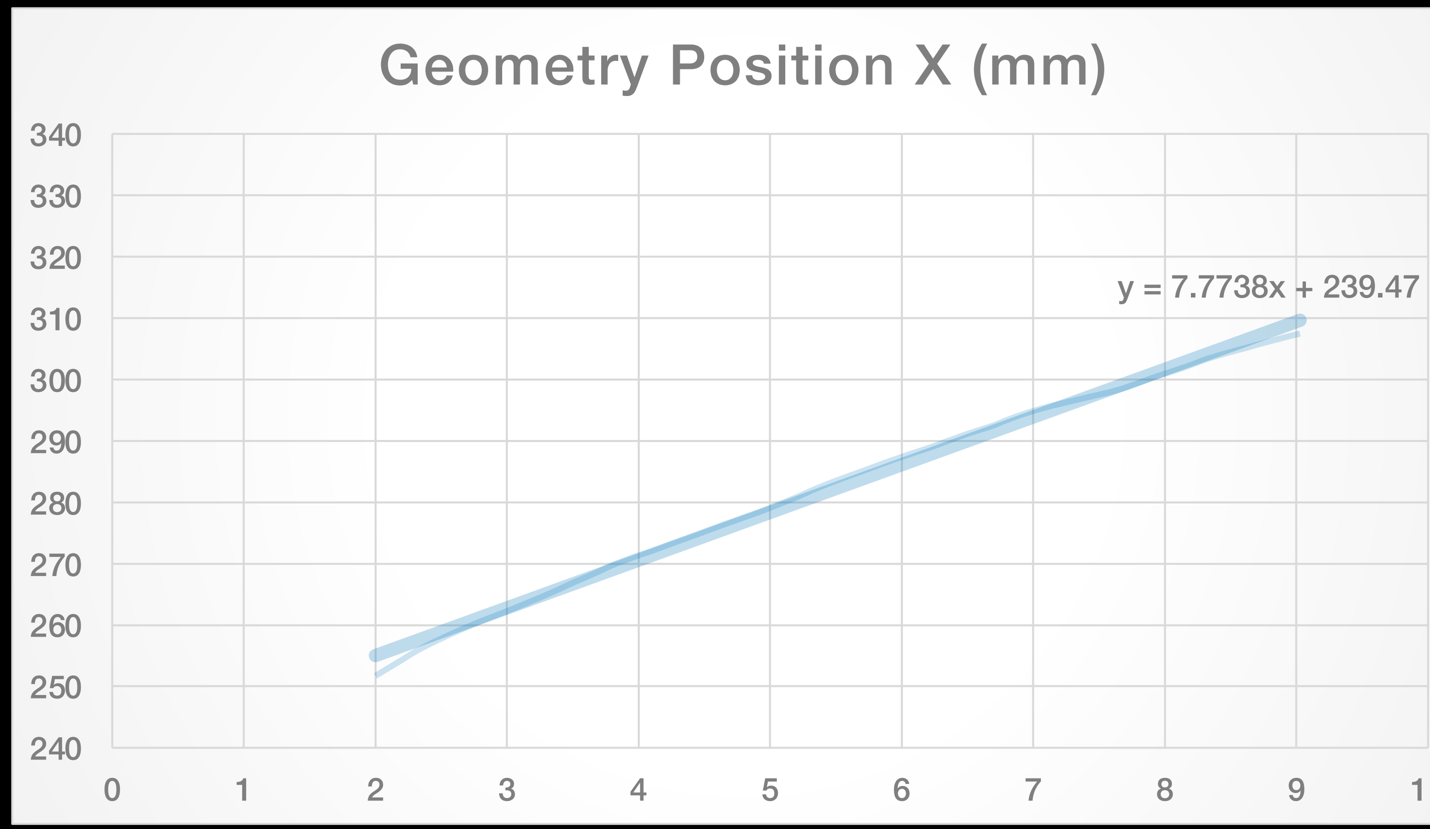
Technical Goals Screw Propulsion

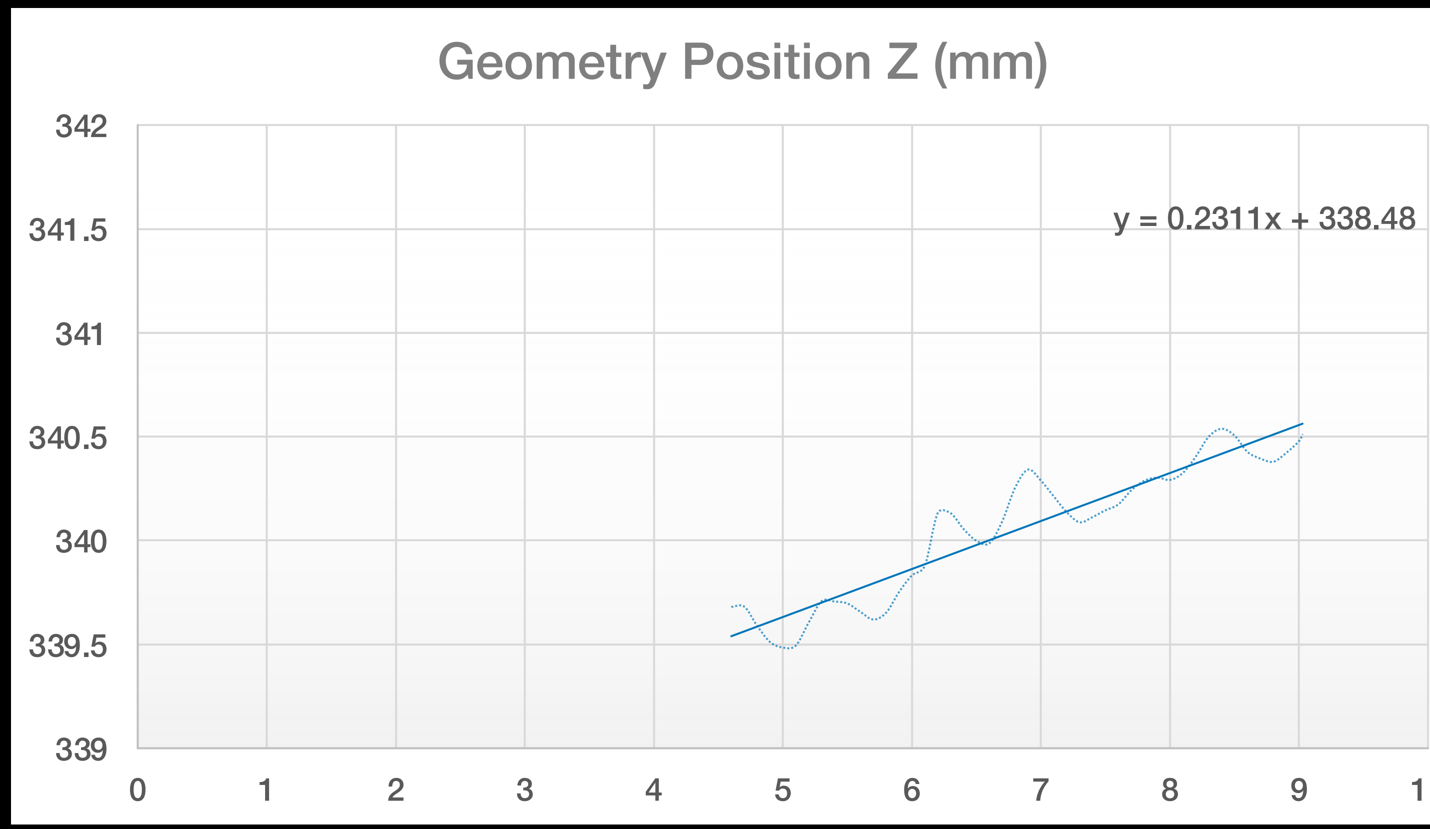
- Screw Propulsion has been proposed for amphibious, icy environments previously including the ZIL-2906 and GPI-72 (Koshurina)
- Modern developments to revive this form for rescue and resource exploration on the Arctic shelf have shown promise (Abramova)
- One difficulty in applying the traditional, counter-rotating dual screw design in a low gravity environment is the instability of a high center of mass (see video)
- Solution is to locate the majority of mass in-line with propulsive vector, creating more inherent stability (EELS)

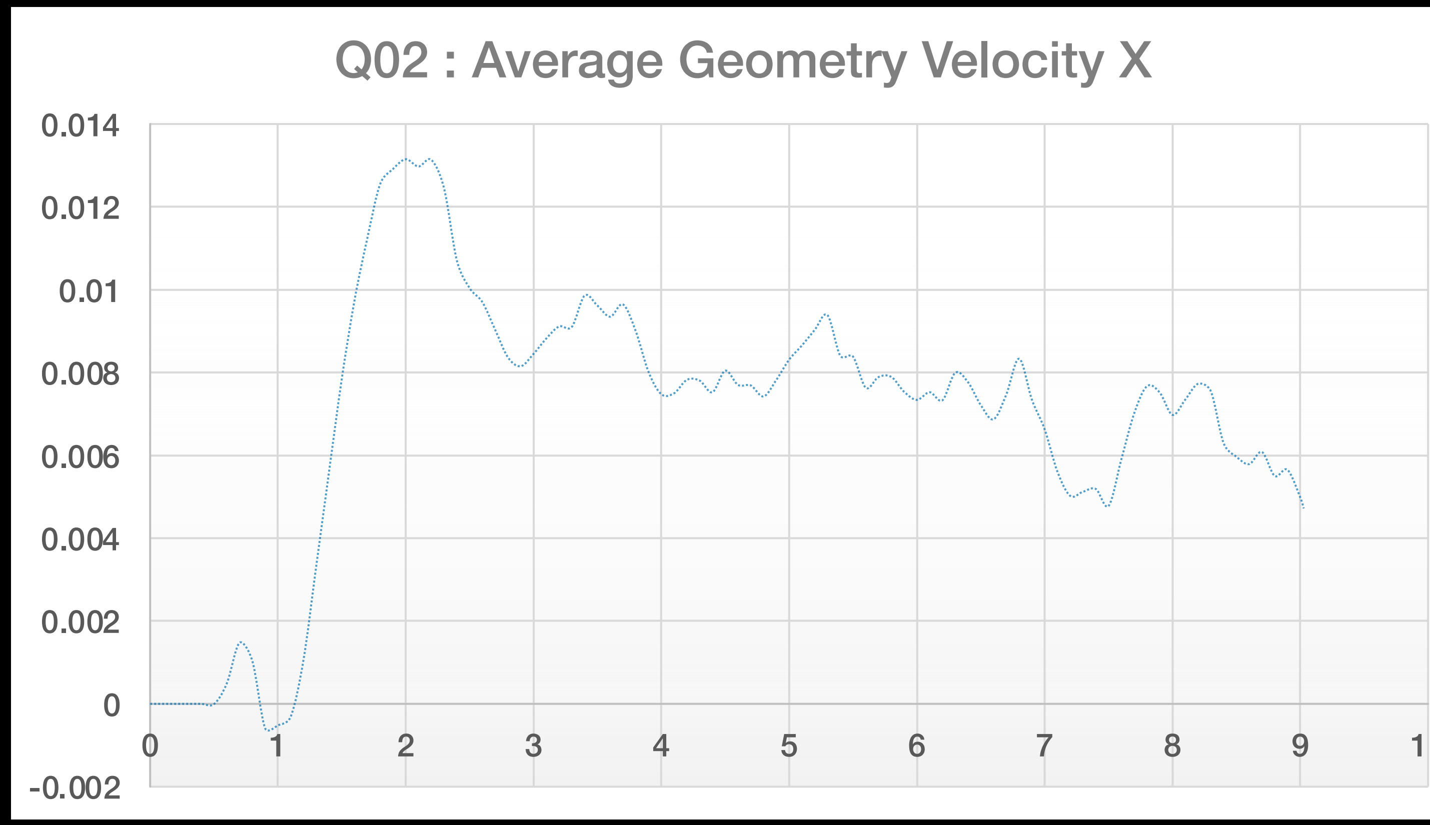


Technical Goals Mobility Simulation

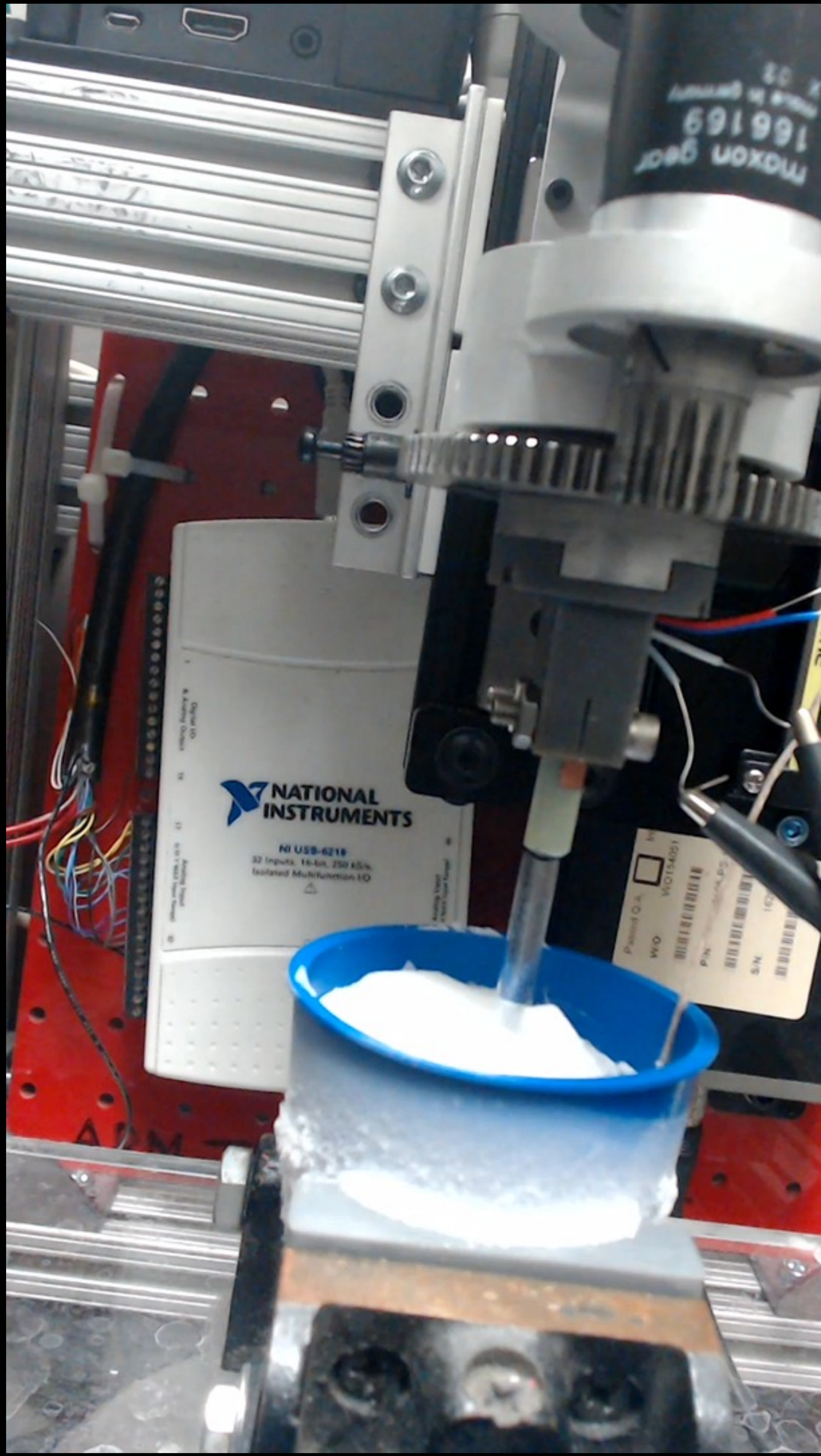








Technical Goals Ice Anchoring



Thermal-Inertial Odometry for Autonomous Flight Throughout the Night

Jeff Delaune, Robert Hewitt, Daniel Lytle, Cristina Sorice, Rohan Thakker, and Larry Matthies

Jet Propulsion Laboratory
California Institute of Technology

Technical Goals Determine Greatest Mass Flux

Artists Concept